I. C. 6877

FEBRUARY 1936

DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

PROGRESS REPORT ON INVESTIGATION OF DETACHABLE ROCK-DRILL BITS

BY

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PROGRESS REPORT ON INVESTIGATION OF DETACHABLE ROCK-DRILL BITS[1]

By McHenry Mosier[2]

INTRODUCTION

The object of this investigation is to determine the field for the use of detachable bits in metal mines of the United States by correlating the data developed through the experience of mines using these bits. Most of the metal-mining districts in the Middle Western and Eastern States already have been visited.

The purpose of the present circular is to define the problem and to discuss the factors that must be considered in order to determine, under different operating conditions, the advantages and disadvantages of this type of bit. Some of the data obtained to date are presented to emphasize points made in the discussion. It is hoped that, as the study progresses, a great many data on drilling will become available. It is evident that since in some cases these data will be confidential they cannot, therefore, be published except as they may be included in average figures covering several different mines. Some data already secured are of this nature. Although considerable information on drilling operations has been gathered at different mines, there were only a few instances in which there were available complete data on all the factors entering into the total cost of drilling with detachable bits and with conventional bits on regular drill steel.

In view of the interest in this subject among metal miners, the Bureau of Mines has completed arrangements whereby mine operators who so desire may avail themselves of the services of one of its engineers, without cost to them, in the making of time studies and assembling of cost data required to obtain a complete picture of the comparative merits of detachable bits and of conventional bits on regular drill steel under the particular conditions prevailing at their individual mines.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U.S. Bureau of Mines Information Circular 6877."

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ACKNOWLEDGMENTS

Most of the information upon which this report is based was derived from the experience at the mines visited and was made available through the courtesy and cooperation of the officials at these operations.

HISTORY

As early as 1865 a patent was granted in the United States for a three-bladed hand-drill bit. This was a detachable bit that was screwed on the drill steel. Since that date a large number of patents have been issued for various types of detachable bits on both hand and machine drill steel.

The use of detachable bits, which is continually expanding, is no longer confined to small mines and contractors. Although such bits are now manufactured from high-carbon steel, which has greatly improved their quality, yet they must be considered as being in the development stage still. One possible method of further increasing their present degree of excellence is through the use of special alloyed steel. In fact, recent experience on the Rand in South Africa with tappet machine drills having hot-milled conventional bits made from chrome-molybdenum drill steel shows a reduction in the cost of drilling. R. S. G. Stokes states[3]:

> The eternal quest for a detachable bit has not been wholly abandoned, but, with the great reduction in number of borers used, the objective has lost much of its appeal; and, with the use of lighter steel for quicker drilling, a serviceable bit and stem have become more difficult to design. Experiments are in progress with a detachable, resharpenable bit, in which the cushioning member in the stem socket for the tapered bit is a lining of soft metal.

BASIC PRINCIPLE OF DETACHABLE BIT

The basic principle of the detachable bit is the construction of a drill steel shank and a bit in two separate units. This permits (1) the bit to be made of a steel that can be hardened to a high degree; (2) the shank or rod to which the bit is attached to be made of a different steel, selected for toughness and resistance to fatigue; and (3) the bit, on account of its small weight and bulk, to be conveniently and economically transported between drill shop and working face.

TYPES OF DETACHABLE BITS

At present six major types of detachable bits are produced in quantity for use in metal mines in the United States. Some of these have several patterns. The first was developed in 1918, while the most recent was produced in 1934. All are illustrated in figure 1. Several other types are now in process of experimental development at various properties. In type 1

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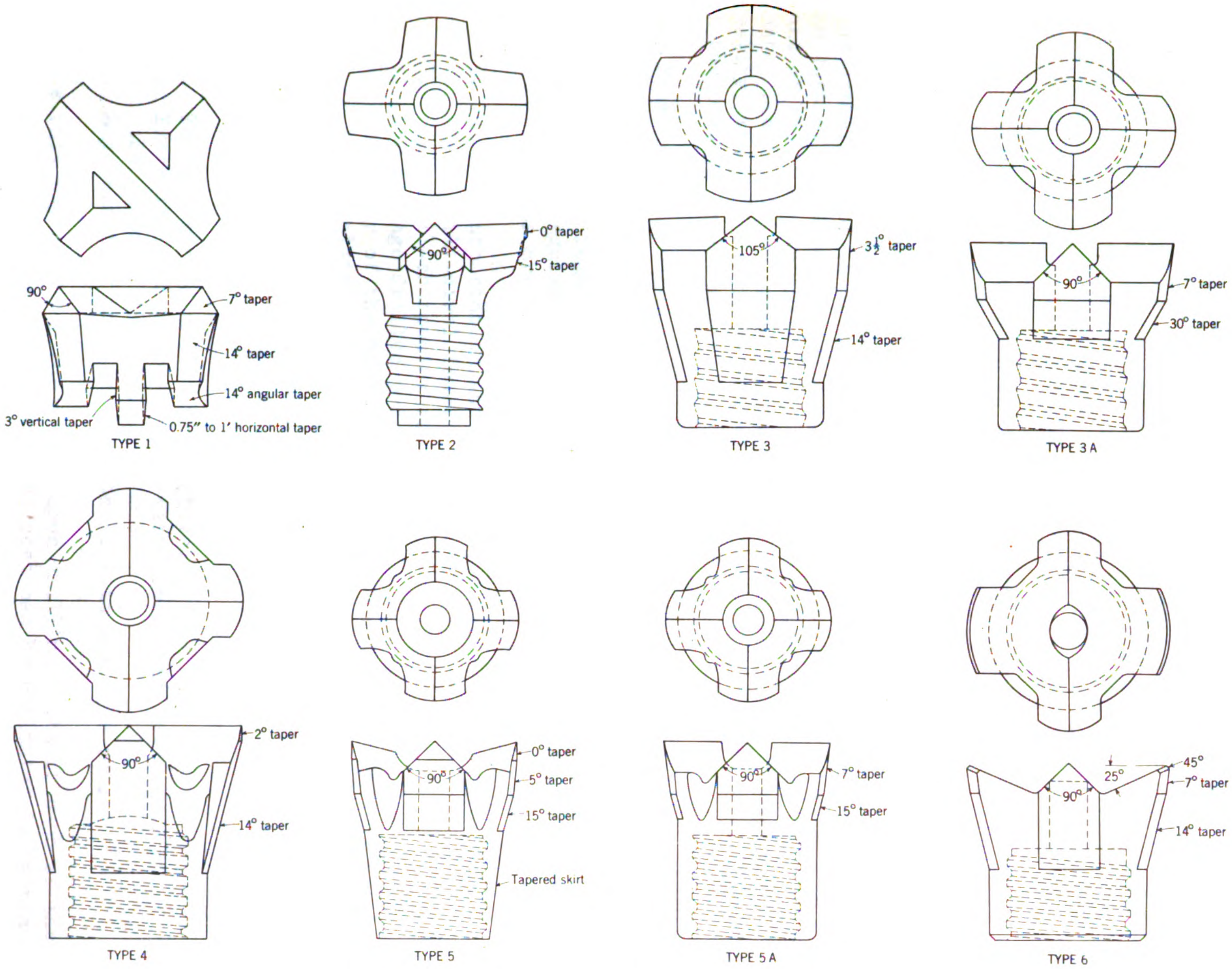
[3] Recent Developments in Mining Practice on the Witwatersrand: Bull. Mining and Metallurgy, London, November 1935.



TYPE 1 TYPE 2 TYPE 3 TYPE 3 A

TYPE 4 TYPE 5 TYPE 5 A TYPE 6

Figure 1.–Some common types of detachable rock-drill bits.

the bit is attached to the shank or rod by means of a tongue-and-groove joint; in type 2 a threaded coupling is used, with the base of the bit bearing on the end of the rod; in type 3 attachment is accomplished by means of a reverse buttress screw thread with a recessed face in the bit contacting the end of the rod; in type 4 a modified acme screw thread is used, with the skirt of bit bearing against a shoulder on the rod; in types 5 and 6 a modified acme screw thread with a recessed face in the bit bearing against the end of the rod is the method employed. Some distinctive designs of detachable bits are shown in the figure illustrating the several types.

FACTORS CONSIDERED IN THE COMPARISON OF DRILLING COSTS

In order to decide whether detachable bits would be advantageous to any particular operation in which regular drill steel with conventional bits is used, it is necessary to have accurate detailed information as to the total cost of all the items involved in each system of drilling. To get a true comparison of their respective merits, it is then essential to reduce the cost of all these items to the cost per foot of hole drilled, for each kind of bit. In preparing these costs, some mines have found that some factor previously regarded as unimportant in its relative effect was, in reality, the critical feature that definitely established the difference in the cost of drilling with the two methods.

From data collected at a considerable number of metal mines, it is possible to point out some of the conditions most favorable to the introduction of detachable bits and those conditions most favorable to the use of conventional bits on regular drill steel. In general, the operating conditions at a mine using regular drill steel that may be said to favor the adoption of detachable bits are the following:

1. High transportation and distribution costs for drill steel.
2. Large drill-steel loss.
3. High drill-sharpening shop costs.
4. Low footage drilled per bit.
5. Inability of the mine shop to produce a bit of uniformly high quality.

Although detachable bits can drill any type of ground, yet, from a cost standpoint, those conditions that are unfavorable to the adoption of detachable bits at their present cost are:

1. The reverse of those listed above.
2. Exceedingly abrasive ground, with consequent rapid loss of the gauge of the bit.
3. Any condition that destroys the bit in a single run.

The only way in which the effect upon drilling costs of each of the various factors entering into the total cost can be evaluated is by means of data developed through actual drilling tests conducted at the particular mine under consideration. At some properties, conditions favoring the use of detachable bits may not prevail generally throughout the mine but may be limited to certain classes of work. At several operations of this kind, regular drill steel is used for ordinary routine work and detachable bits for special jobs. The latter comprise such tasks as long-hole drilling by means of jointed rods and the drilling of headings that are particularly inaccessible and faces that cannot be drilled satisfactorily with conventional bits forged on regular drill steel at a local shop.

The tangible factors that affect the total cost per foot drilled with detachable bits and with conventional bits on regular drill steel are enumerated below:

1. Cost of transporting drill steel and bits from sharpening shop to working face and return.
2. Shop operating expense for reconditioning drill steel and bits.
3. Cutting speed or rate of penetration.
4. Number of feet drilled per bit dulled.
5. Feet drilled per machine shift.
6. Loss of drill steel from all causes.
7. Drill machine repairs.
8. Hazards in transportation and use of drill steel and bits.
9. Capital expense.

DISCUSSION OF FACTORS

The following discussion of these factors presents some preliminary operating data for detachable bits and for conventional bits on regular drill steel, and shows their relation to the cost per foot of hole drilled.

1. Cost of transporting drill steel and bits from sharpening shop to working face and return. The cost of transporting drill steel, with its corresponding reflection in the cost of mining, is often the most difficult to determine of all the drilling expenses for any given mine. Yet, by means of time studies covering a long enough period, even this elusive cost can be determined with a reasonable degree of accuracy. Included in cost of transportation is the expense of delivering steel or bits from the shop to the collar of the shaft, of handling them through the shaft, and of distributing them on the mine level or through manways and raises to the working face, as well as the expense of returning them to the shop. When mines are operating at a reduced rate of output, the true cost of transporting the steel may not be apparent, but when operations approach the maximum rate of production this cost becomes more obvious. In those mines where supplies are handled through an ore-hoisting compartment of a shaft, the loss of effective hoisting time will become more serious as maximum capacity is approached. At most mines the usual procedure in segregating costs is to charge transportation with its proportionate share of hoisting expense, based on the number of trips made through the shaft and the time involved. In mines where tool nippers are employed underground, the time they spend in handling steel is, of course, included in the transportation charge. When the miners themselves transport the drill steel, the question arises as to whether this transportation is a debit against the cost of drilling. In the case of miners

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drilling in open stopes, particularly with sublevels, and in other similar instances, where there always are plenty of faces to drill, the more time the miners lose in handling steel the less drilling can be done. When miners are employed on development work with only one working face available, it may be more difficult to utilize effectively the time saved in handling drill steel through the adoption of the detachable bit. Even in such an instance, there is frequently enough related work in the heading itself to occupy the miners fully after the round is drilled, so it would appear that the actual time spent by the miners in transporting drill steel is a definite and proper charge against the cost of drilling.

2. Shop-operating expense for reconditioning drill steel and bits. In the shop-operating expense, in addition to labor and supplies, compressed air for operating drill-sharpening machines should be measured and charged for at the average unit cost for air compression. There are also included in this shop expense such items as fuel, electricity, water, tools, and repairs to equipment. Thus, the total cost per bit sharpened can be found and then converted into cost per foot drilled.

At some mines, detachable bits are reground two or more times and then discarded; at other mines, instead of discarding, retempering is introduced with subsequent additional regrinding; at one mine this latter practice is followed by reforging, retempering, and still further regrinding. On the present market, the original purchase price of a detachable bit plus the shop cost of reconditioning is normally greater on a "times-used" basis than the corresponding cost of only those particular items for regular drill steel. To determine whether there is a net saving through the use of detachable bits, all the other tangible factors must be considered.

3. Cutting speed or rate of penetration. With other conditions remaining constant, the design or pattern of the bit and its gage largely influence the cutting speed. Many things enter into the design of a bit. The first consideration is the general type, as, for example, chisel bit, cross bit, or rose bit. Then follow such details as clearance tapers, whether single or double, and the degree of each; the angle between faces, which may be acute, obtuse, or 90 degrees; the dimensions of the wings, including their heighth and width; the amount of reaming effect from the edges of the wings; and the position of the hole through the bit, which may have a center or side outlet. In general, the usual patterns and designs of bits in common use with regular drill steel are duplicated in detachable bits.

One of the principal points in design of bits is the amount of clearance for cuttings required for rapid drilling in a given formation. Small gages drill faster than large gages. One mine reports a 58-percent increase in drilling speed in granite for a 3/4-inch decrease in the gage of the bit, which, in this instance, is roughly inversely proportional to the area of the hole drilled. Another mine, using conventional bits on regular drill steel, has effected appreciable economy in the cost of mining by decreasing the size of the drill hole and increasing the strength of the explosive. The saving resulting from faster drilling with smaller-gage bits is far

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greater than the increased cost of the higher-grade explosive required to give the same fragmentation of the ore. At this mine, the "starter" for a 10-foot hole with its 1-3/8-inch gage is smaller than the "finisher" used at many mines, and the drilling speed has been increased correspondingly.

The tendency among users of detachable bits is toward smaller gage changes. Most of these operators use a "following gage", in which the bits, instead of being ground down to a predetermined gage, are first sharpened and then sorted into sizes having, at some mines, as small a differential as 1/64 inch. As conventional bits on regular drill steel in normal practice cannot be made with such a small gage change, the advantage in this regard is with the detachable type. However, for very small gages, the detachable bit is at a comparative disadvantage. For the types now in commercial production in the United States it is not possible to construct a bit with as small a gage as can be forged on regular drill steel of corresponding cross section. Ordinarily, the smallest detachable bit is 1-1/4-inch gage, and this is used on a 7/8-inch rod.

The hardness and the quality of the cutting edge of a bit are factors that depend on the composition of the steel and the corresponding heat treatment.

One of the largest items in the cost of drilling is the labor cost per foot of hole for operating the drill. The cutting speed largely influences this cost, though not in direct proportion, because the drill is actually cutting during only a small proportion of the total lapsed time of any shift. With a constant air pressure, the compressed-air consumption per foot of hole depends in a great measure on this cutting speed. At 10 mines where comparative records were available the average cutting speed with detachable bits was 22 percent faster than with conventional bits on regular drill steel.

4. Number of feet drilled per bit dulled. The footage drilled per bit dulled has as much influence on the cost of drilling as the cost of the bit itself. It is the factor employed in converting the cost per bit into cost per foot of hole drilled. The number of feet drilled per bit dulled with conventional bits on regular drill steel depends, in no small measure, upon the degree of perfection attained in forging and hardening the bit. This, in turn, depends on the skill of the personnel in the local shop as well as on the sharpening and heating equipment and the means for heat control. This process requires specialists, but, at the average mine shop, it is not always possible either to procure or to retain the services of men properly trained in such metallurgical technique.

In the manufacture of the detachable bit all processes are under positive scientific control by skilled operators with the best equipment obtainable. The result is an absolutely uniform product capable of the maximum service possible for the carefully selected steel specified in its construction. The steel now commonly used for manufacturing detachable bits in the United States has a higher carbon content than regular drill steel, with consequent greater hardness and resistence to abrasion. These factors give a longer life to the bit.

Fourteen mines that have had extensive experience with detachable bits show an average increase in footage drilled per bit of 28 percent over that of the the conventional bit on regular drill steel.

5. Feet drilled per machine shift. The footage drilled per machine shift establishes the labor cost per foot of hole. Under circumstances that permit continuous drilling, the cutting speed becomes more important as a factor in the footage drilled. Any increase in cutting speed that might result from the introduction of the detachable bit is at once apparent in the total number of feet drilled. Of course, any delays in drilling due to shortage of sharp steel will increase the labor cost per foot of hole. In such a case, particularly with regular drill steel, miners may use extremely dull bits, which slow the drilling speed and increase machine-drill repairs. On the other hand, when only the required footage for a given round can be drilled for lack of sufficient working faces to keep the machine drill employed during the entire shift, the fixed footage is, in fact, the maximum attainable, regardless of increased cutting speed. Even in this case the shorter drilling period is advantageous, as it reduces the compressed-air consumption and also permits the miner to do other related work.

6. Loss of drill steel from all causes. The loss of drill steel includes wastage in the process of heating and forging the bit, abrasion in actual drilling operations, breakage of drill steel, whether from normal fatigue or from improper handling in the shop and in transportation, and the disappearance of unaccounted-for pieces.

Abrasion of bits in actual drilling is reflected by the loss in gage. It is less with detachable bits than with regular drill steel at the mines visited. At one property, which kept precise records of drilling tests, the detachable bits showed only one-sixth as much abrasion per foot of drilling as the conventional bits on regular drill steel.

The miner who uses detachable bits has so few rods in service that he finds it much easier to avoid their unaccounted-for loss than with the larger required number of pieces of regular drill steel.

On a fixed scale of operations, the total loss of drill steel is measured accurately by the normal average monthly or annual amount of replacement steel required to keep a constant stock in service. For regular drill steel it may be as low as 0.007 or as high as 0.770 pound per foot of hole drilled. At four of the mines visited there was available a comparative record of the loss of drill steel for the two classes of bits. The average reduction in this loss through the adoption of detachable bits at these four mines was 48 percent.

7. Drill machine repairs. A correct comparison of the cost of drill-machine repairs before and after the introduction of detachable bits cannot be made until a long enough time has elapsed following the change to eliminate entirely the influence of the use of regular drill steel. Thus, under the new conditions, it might be a year before the normal cost would be evident.

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To get a true comparison of these costs, all other factors, such as the formation drilled, lubrication of the machine drills, and general mine-operating conditions, must remain constant. No reliable comparative figures for drill-machine repairs are available as yet at the mines visited, although several properties that have changed to detachable bits show a tendency toward a smaller drill-machine repair cost. The most plausible explanation for this is the suggestion that the detachable bits usually are not run to as dull a cutting edge as are regular bits, and therefore do not impose as severe shock on the drill machine.

8. Hazards in transportation and use of drill steel and bits. It is sometimes difficult to eliminate all the hazards involved in transporting many comparatively heavy pieces of regular drill steel of variable lengths. From a safety viewpoint a rather hazardous condition is brought about when these pieces are handled in and out of a skip or cage and again on the mine levels under live trolley wires. The use of detachable bits reduces these hazards because fewer rods are required.

It is customary to strike the detachable bit lightly in order to loosen it. By using a small hammer of mild steel for this purpose, the danger from flying splinters of steel is eliminated.

9. Capital expense. This includes the cost of construction of the drill-sharpening shop building, the cost of the shop equipment and of its installation, together with the cost of the initial stock of drill steel and bits.

For a large operation having many bits to sharpen every day, less equipment is necessary for reconditioning detachable bits than for conventional bits on regular drill steel, and there are fewer pieces of long drill steel to handle. Consequently, a smaller shop building and a lower construction cost is required. But, for a smaller operation the reverse is true; because, after adopting detachable bits it is usually found convenient to have a drill-sharpening machine for shanking and other work; and, in addition, it is necessary to install apparatus for grinding bits. If detachable bits are rehardened, muffle furnaces and especially designed quenching arrangements will be necessary for the best results in this work. The kind of equipment required for preparing one end of the rod to receive the bit depends upon the particular method of attachment used. The reconditioning of bits and rods at a very small operation without shop facilities sometimes can be done at some other plant with suitable equipment for such work. Thus further capital expense can be avoided, though probably at an increased unit cost for reconditioning bits and rods.

A smaller stock of drill steel is required for making detachable bits than for regular bits. At one mine only one-sixth the amount of drill steel formerly used was required after the use of detachable bits was adopted. The more remote and inaccessible the location of the mine, the more important this item of inventory becomes, because of the high delivery charges for drill steel.

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The cost of making up the initial stock or sets of regular drill steel and the rods for detachable bits is sometimes included in this inventory cost under capital expense.

The capital expense can be translated into cost per foot drilled by adding the depreciation to the annual interest on the investment and finding the ratio of this sum to the annual footage drilled.